is lowest. The temperature drop after the rain ceases and the blue sky comes may also be noted. This can be classified as small, normal, or large. The rapidity or rise of the barometer may also be classified as rapid, normal, or slow.

VI. LIMITATIONS.

This classification of the sequence of events in passing from rain to blue sky applies geographically to New England or the Middle Atlantic States. This normal distribution of the meteorological elements about a low is, however, but slightly different for any part of this country and not very different for the Atlantic Ocean or for Europe.

Furthermore, it has always been a low which so moves that an observer passes through its southern quadrants, that has been considered. Now for the northwestern part of the United States this is nearly always the case. A wind that backs instead of veers is very unusual except possibly near the seacoast and in the extreme northern part. The sequence of events would be entirely different, and this has not been considered.

Furthermore, it is the winter type of storm with steadily falling rain or snow which has been considered rather than the summer type with the sultry weather and thundershowers. The best way to characterize the difference between the summer and winter type is to liken it to a machine. In the winter type the machine runs smoothly. In the summer type the machine clogs and stops and then by a thundershower is jerked forward to where it ought to be. The sequence of events goes forward by jerks rather than smoothly.

Furthermore, exact figures have not been given. It would require ten years of careful observation to do this, and but little would be gained. The value is in the classification. For example, it makes little difference whether about one low in seven has a sharp wind-shift line or it is finally found that for a definite place for a definite period of ten years it is exactly 17 per cent. This classification is based upon two or three years of casual observation and one year of critical observation to test the classification at Williamstown, Mass.

VII. SUMMARY.

As was stated at the beginning, the purpose of this article is to attempt a classification of the various methods of transition from rain to blue sky. For example, it may be said of a certain passing low which caused the rain, that the wind veered steadily instead of changing suddenly; that the direction of the cloud motion was ahead of the wind direction; that an upper cloud layer was seen for a short time; that the time required for showing blue sky was normal. It might also have been stated that the lowest pressure came with the wind from the southwest, that the temperature drop was normal, and that the pressure increase was rapid. It will thus be seen that this classification would give to anyone familiar with the various methods of transition, a definite picture of the characteristics of the passing storm. It will also add much pleasure to watching this oft occurring transition to know the various ways in which it may take place and the one in progress in the instance under observation.

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SQUALLS AND THE PREDICTION OF TORNADOES.

By E. DURAND-GRÉVILLE.

[Dated Paris, Mar. 30, 1913. Translated for the Monthly Weather Review.]

INTRODUCTORY NOTE.

The International Conference of Directors of Meteorological Observatories, which met at Innsbruck, Austria, in September, 1905, listened to an enthusiastic paper on the phenomena of squalls by M. E. Durand-Gréville. After his address Prof. H. Hildebrandsson suggested that the conference appoint a commission on squalls, its functions to be analogous to those of the International Commission on Clouds appointed by the International Meteorological Committee. Favorable action by the Conference resulted in the appointment of such a Commission composed of MM. Hildebrandsson (Upsala), Shaw (London), and Durand-Gréville (Paris).

M. Durand-Gréville was long an active student of squall phenomena, and this REVIEW has already published an exposition of his discoveries in this branch of meteorology. The publication of the present paper has been delayed by administrative changes that were impending at the time of its receipt. The Editor regrets to announce the death of its author on January 20, 1914.

SQUALLS.

What has come to be known as the "law of squalls" did not present itself to my mind at one time. Several years previous to 1890, being intrusted with the meteorological articles in the Grande Encyclopédie, I had first made myself acquainted with the earlier works, or at least with the greater number of them, notably with those of Ciro Ferrari, who, according to the expression of Hildebrandsson, was "the one who had done the most" for the knowledge of thunderstorms; also, of course, the works of Marié-Davy, written under the direction of Le Verrier.

The latter had given the simplest possible definition of a thunderstorm, viz, "any disruptive electrical discharge in the atmosphere." The definition had become complicated little by little, in proportion as the details had been studied and various brusque changes at the time of the thunderstorm had been observed, such as rise of the barometer; increase in force and change of direction of the wind; fall of temperature; increase of relative humidity, etc. I shall tell you why it seems necessary to revert to the original definition of the thunderstorm and to restore to the squall its personality, the squall serving only—as occasional cause—to rouse up the thunderstorm *at the moment* when it arrives from a distance on large cumuli previously formed.

In studying attentively the thunderstorm isochrones of Marié-Davy and more especially those of Ferrari, I perceived that there appeared to be a real correspondence between two "thunderstorm spots" not too far distant from one another and that, in certain cases, the isochrones of the two "spots" could easily be connected. If one sought to verify what took place between the two "spots," one would discover the existence of a wind squall, of a barometric "hook" (crochet), etc. This work of verification was done slowly and fragmentarily, but in the end I was persuaded—without, however, having any very tangible proof of it—that the isochronous line of a violent squall passing over a place in the morning without evoking a thunderstorm, would continue its course toward the east, until the time—especially in the afternoon—when it would rouse a thunderstorm at points properly prepared for it.

Chance furnished me with a sort of *a posteriori* proof of this. On August 27, 1890, I had witnessed a very violent squall which passed over Angers just before midday, unaccompanied by thunderstorm, rain, hail, or even cloudiness. The first observatory that I was able to communicate with was that of La Baumette, 5 kilometers from Angers. I found there all the phenomena of pressure, force and direction of wind, and temperature that I had expected. I noted the time of beginning, maximum, and end of all these phenomena and made copies of the tracings or had them photographed. The same was done for the other observatories in the neighborhood and afterwards for all those in Europe, and I thus obtained proof that the squall occurred at a given instant over a length of more than 1,200 kilometers, and formed a narrow band oriented north-south, which moved with a uniform

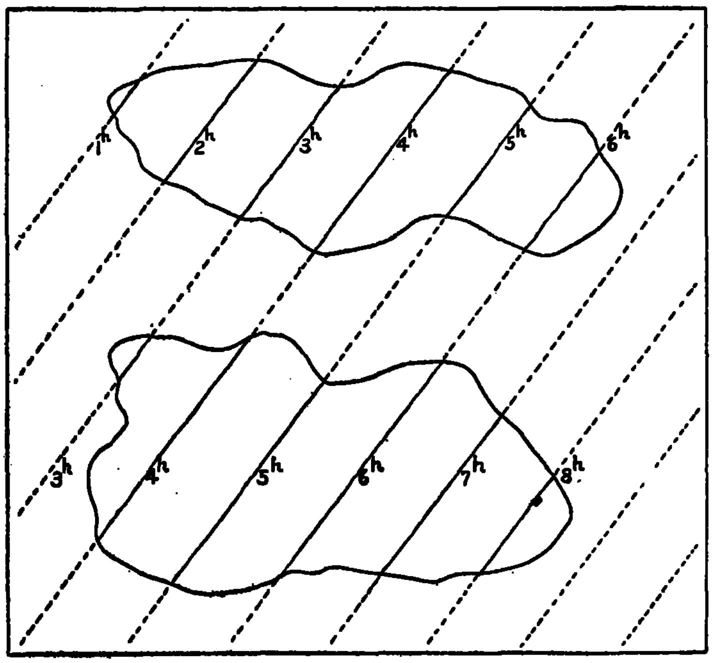

FIG. 1.—Alignment of isobronts in "thunderstorm spots."

velocity of about 60 kilometers per hour. This is what I denominated the "squall-zone" (*ruban de grain*), giving the designation of "squall-line" (*ligne de grain*) to the front border of this space.[1]

Thus, as might have been foreseen, the "zone" provoked the thunderstorm at all the points that were properly prepared, and these were very numerous over all the northeast of France and in some parts of Germany.

Two small "thunderstorm spots" (*taches orageuses*) appeared in the south of France toward 8 p. m.; finally a last thunderstorm occurred about 9 p. m. over Berlin itself, precisely at the moment when the "squall-zone" reached that city. The "squall-zone" then continued its course eastward and arrived over St. Petersburg the next day (August 28) at 5 p. m.

Thus the question was solved; the "squall-zone," which carries with it over the places that it passes, all the phenomena of the squall, has an independent existence. It may come from a distance, it may move for more than 30 hours across the whole of Europe, and it is *at the instant* of its passage that the thunderstorm most frequently bursts in places where the local conditions (previous existence of very large cumuli) are favorable.

We say "most frequently" in order not to ignore "heat thunderstorms" (*orages de chaleur*) which occur spontaneously and without wind; for these latter, it is only necessary that a calm, humid atmosphere and a hot sun favor the formation of very high cumulus summits, serving as electric excitants between the region of cirrus, charged with positive electricity, and the surface of the earth, charged with negative electricity.

Having subsequently charted the isobars for every two hours, or, when the data permitted for every hour of the day in question, I obtained proof that the isobars, which everywhere else are nearly circular, form a zigzag. Abercromby had already observed the eastern and intermediate branches (V-shaped isobars) as of this zigzag as well as the "trough" which is identically my "squall-line." When I write a volume on squalls, I shall render my homage and all the priority that belongs to him, to one of the greatest meteorologists of the last century, and to the greatest of my predecessors in the study of the question of squalls.

Another result obtained from the examination of the same charts with isobars drawn for millimeter-intervals, was the proof that the "squall-zone"—in spite of some irregularities—*corresponds exactly to a radius of the low* of which it forms a part.

TORNADOES.

These preliminaries being borne in mind, we now arrive at the question of tornadoes. In my second memoir entitled "Les grains et les tornades",[2] I showed that tornadoes *always* originate on the front edge of the "squall-zone."

Nothing, therefore, would be easier, when a very violent "squall-zone" advances from the west toward the east of the United States, than to warn by telegraph the central bureau at Washington which, after receiving a dozen such telegrams, could chart on a map the hours of the passage of the squall over such and such places, would know the trend of the "squall-zone," and the velocity and direction of its propagation parallel to itself. The bureau would thus be informed, *at least several hours in advance*, of the times at which the "squall-zone" would pass each of the points situated more to the east. Further telegrams would, however, be necessary in order to foresee the case where the "zone" might have changed its form and its velocity of translation; but these two factors are generally almost constant and change very slowly.

In each city a warning signal, a "squall cone," similar to the "storm cones" at ports, would indicate very nearly the hour of the arrival of the "squall-zone." Being advised of the passage of a very violent squall about that time (it would often be possible to tell the time within approximately 15 minutes) and that this severe squall might—like all violent squalls—be accompanied by a tornado at one or more unknown points *on its front edge*, the inhabitants would take precautions against the wind of a *certain* storm and a *possible* tornado. As soon, however, as the front edge had passed, the danger of a tornado would be over, and the people would have to guard against the wind only.

It is sometimes said that tornadoes are generated at any time in the interior of a "thunderstorm belt" (*bande d'orage*), thus confounding the thunderstorm with

[1] *See:* Les grains et les orages, Annales du Bureau central météorologique de France. 1892.
See also: Squalls and Thunderstorms, Monthly Weather Review, June, 1909, v. 37, p. 237.

[2] Annales du Bureau central météorologique de France, 1894.

the squall which is its occasional cause. But one must not conclude from this that the tornado may generate in any region of the "squall-zone." This error has arisen from the rare cases of several "squall-zones" following each other at short distances and separated by brief intervals of relative calm and inverse rotation of the wind. We have said that when the "squall-zone" has, for example, a north-south direction and the center of the depression is to the north of the observer, the wind to the right and left of the "squall-zone" is weak and southwesterly, while it is between west and northwest and violent within the "zone."

It would therefore be necessary for the central bureau to be informed whether the "squall-zone" passing over the western part of the United States, is simple or whether it is composed of several closely associated "squall-zones" [see Monthly Weather Review, v. 37, p. 239]; in the latter case, the cone for "*certain* squall with *possible* tornado" should not cease to announce the danger of a tornado until after the passage of the last of the parallel zones. When this has passed all danger of a tornado would be over until the arrival of a new "squall-zone."

This very simple method of prediction that we recommended 17 years ago—if not for tornadoes, which are very rare in our climates, at least for violent squalls - has not yet been adopted in France. It seems, however, as if it soon would be, in view of the present very marked movement in favor of agricultural forecasts. But we should be very happy if the application of the *law of squalls and tornadoes* were to be made in a country which tornadoes seem to have selected as the land of their predilection. The consequences of squalls and tornadoes can not be entirely averted, far from it, but if the people were warned of the danger, much damage could be prevented and, above all, by seeking places of safety many lives would be saved. There are, it appears, at present in America shelters erected against tornadoes; but they would be much more useful if people were informed of the *exact* hour and of the *very short* duration of the danger.

EVAPORATION FROM SNOW AND ERRORS OF RAIN GAGE WHEN USED TO CATCH SNOWFALL.

R. E. HORTON, M. Am. Soc. C. E.

[Dated Albany, N. Y., Jan. 28, 1914.]

The sketch (Fig. 1) shows the condition of the galvanized rain gage can at the end of the storm of December 26, 1913, at Albany, N. Y. Gage located at elevation about 220 above tide. At this point the entire storm fell as snow, the first portion being very damp. The first fall down town at about tide level occurred as rain. It was apparently this first snow which stuck to the outside of the gage, as shown in the sketch. This barrier on the edge of the can undoubtedly greatly increased the deflection of the later snow so that only 0.43 inch water equivalent entered the gage, although the total snowfall on the ground was 1.41 inches. There was not enough wind to cause any drifting of this snow for eight days, and there was practically no melting of the snow during this time, as the temperature was constantly very low. What melting occurred was apparently confined to about one-eighth to one-fourth inch at the surface, but was not sufficiently intense to form a solid crust. The cold weather changed the crystal form and the snow became very hard and resembled coarse granulated sugar after the first two or three days. The settlement of the snow mass is shown in the table and also the amount of loss by direct evaporation. In the first determination of the amount of snowfall samples were taken at several different locations in a yard about 35 by 100 feet. These were found to agree closely, although the depth of snow varied about 1 inch. Samples used to determine the evaporation were all taken within an area of 1 square yard. To get these samples the galvanized gage can was thrust down over the cylinder of snow, a thin-edged shovel was slipped under the edge of the can, and care was taken to get all of the snow from the ground surface.

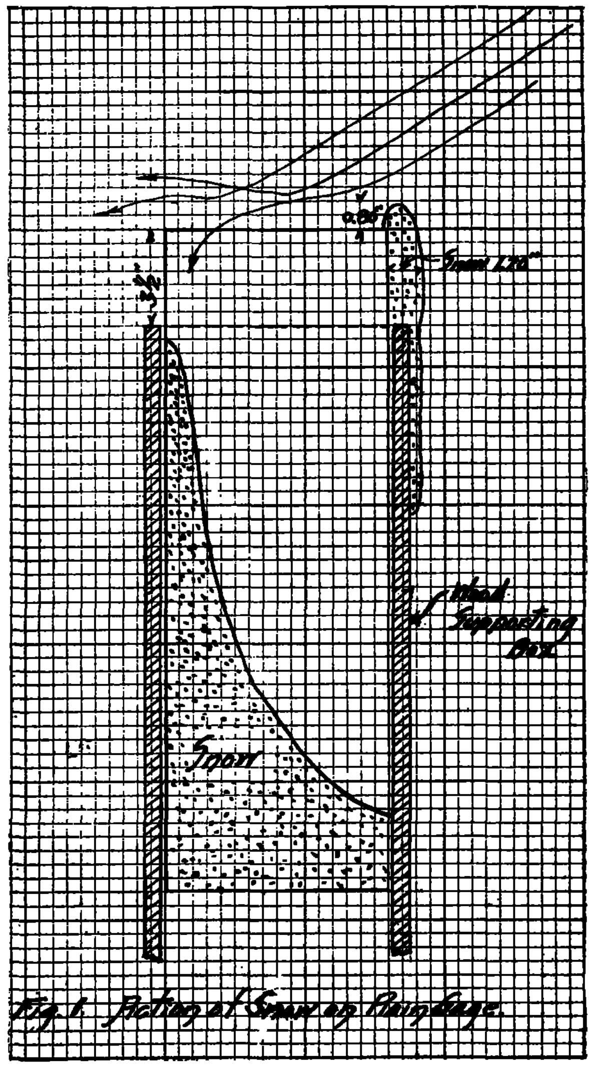

FIG. 1.—Action of snow on rain gage.

Depth, water equivalent, and evaporation loss from snow, Albany, N. Y., Dec. 26, 1913, to Jan. 4, 1914.[1]

Date.	Number of tests.	Depth on ground.	Water equivalent.		Total loss.	Loss per day.	Maximum temperature.[2]	Mean wind movement.[2]
			Inches.	Ratio.				
		Inches.			*Inches.*	*Inches.*	° *F.*	*Mis./hr.*
Dec. 26, 1913	4	11.25	1.41	0.125	0	0	22	14.6
Dec. 27, 1913		10.00					19	9.3
Dec. 28, 1913		9.50					18	3.0
Dec. 29, 1913		9.00					23	3.0
Dec. 30, 1913		8.00					37	6.8
Dec. 31, 1913		7.50					32	6.3
Jan. 1, 1914	2	7.00	1.22	0.174	0.18	0.028	19	7.5
Jan. 2, 1914	2	7.12	1.24	0.174			21	3.8
Jan. 3, 1914		6.50					36	6.2
Jan. 4, 1914	4	6.00	1.16	0.193	0.25	0.028	39	12.6

[1] Tests made about 4 p. m. each day.
[2] At United States Weather Bureau. Data contributed by George T. Todd, Local Forecastr.